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Correlation between case mix index and antibiotic use in hospitals

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Weber, R

Abstract: **BACKGROUND:** To compare the quantitative antibiotic use between hospitals or hospital units and to explore differences, adjustment for severity of illness of hospitalized patients is essential. The case mix index (CMI) is an economic surrogate marker (i.e. the total cost weights of all inpatients per a defined time period divided by the number of admissions) to describe the average patients' morbidity of individual hospitals. We aimed to investigate the correlation between CMI and hospital antibiotic use. **METHODS:** We used weighted linear regression analysis to evaluate the correlation between in-hospital antibiotic use in 2006 and CMI of 18 departments of the tertiary care University Hospital Zurich and of 10 primary and 2 secondary acute care hospitals in the Canton of Zurich in Switzerland. **RESULTS:** Antibiotic use varied substantially between different departments of the university hospital [defined daily doses (DDD)/100 bed-days, 68.04; range, 20.97-323.37] and between primary and secondary care hospitals (range of DDD/100 bed-days, 15.45-57.05). Antibiotic use of university hospital departments and the different hospitals, respectively, correlated with CMI when calculated in DDD/100 bed-days [coefficient of determination (R^2), 0.57 ($P = 0.0002$) and 0.46 ($P = 0.0065$)], as well as when calculated in DDD/100 admissions [R^2 , 0.48 ($P = 0.0008$) and 0.85 ($P < 0.0001$), respectively]. **CONCLUSIONS:** Antibiotic use correlated with CMI across various specialties of a university hospital and across different acute care hospitals. For benchmarking antibiotic use within and across hospitals, adjustment for CMI may be a useful tool in order to take into account the differences in hospital category and patients' morbidities.

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Correlation between case mix index and antibiotic use in hospitals

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Background: To compare the quantitative antibiotic use between hospitals or hospital units and to explore differences, adjustment for severity of illness of hospitalized patients is essential. The case mix index (CMI) is an economic surrogate marker (i.e. the total cost weights of all inpatients per a defined time period divided by the number of admissions) to describe the average patients' morbidity of individual hospitals. We aimed to investigate the correlation between CMI and hospital antibiotic use.

Methods: We used weighted linear regression analysis to evaluate the correlation between in-hospital antibiotic use in 2006 and CMI of 18 departments of the tertiary care University Hospital Zurich and of 10 primary and 2 secondary acute care hospitals in the Canton of Zurich in Switzerland.

Results: Antibiotic use varied substantially between different departments of the university hospital [defined daily doses (DDD)/100 bed-days, 68.04; range, 20.97–323.37] and between primary and secondary care hospitals (range of DDD/100 bed-days, 15.45–57.05). Antibiotic use of university hospital departments and the different hospitals, respectively, correlated with CMI when calculated in DDD/100 bed-days [coefficient of determination (R^2), 0.57 ($P = 0.0002$) and 0.46 ($P = 0.0065$)], as well as when calculated in DDD/100 admissions [R^2 , 0.48 ($P = 0.0008$) and 0.85 ($P < 0.0001$), respectively].

Conclusions: Antibiotic use correlated with CMI across various specialties of a university hospital and across different acute care hospitals. For benchmarking antibiotic use within and across hospitals, adjustment for CMI may be a useful tool in order to take into account the differences in hospital category and patients' morbidities.

Keywords: diagnosis-related groups, DRGs, benchmarking, methodology

Introduction

Increased and inappropriate antibiotic use among outpatients and in hospitals has been noted worldwide,^{1–4} and the association between antibiotic use and the emergence of antibiotic resistance is well established.^{5–7} Antibiotic stewardship programmes in hospitals are considered a major tool to address these problems.⁸ The quantitative and qualitative assessment of antibiotic use is crucial to develop antibiotic policies and is the mainstay of antibiotic stewardship programmes. The amount of antibiotic use has been found to vary widely across countries in the ambulatory as well as in the hospital setting.^{9,10} Reasons for these variations may include different antibiotic policies, physicians' education, culture-dependent patients' expectations, varying antibacterial resistance rates and differences in measuring antibiotic

use. The ATC/DDD system promoted by the World Health Organization is the standard method for reporting antibiotic use.¹¹ However, different formats for measuring and reporting antibiotic use are still applied in the current literature.^{1,4,12,13}

Clinicians often justify high antibiotic use in their particular setting with differences in patients' morbidities. Several scores are used to classify patients' severity of illness based on their co-morbidities in clinical studies,^{14,15} but, unfortunately, there is no straightforward tool to routinely obtain morbidity scores for all inpatients of an entire hospital. Using hospital economic data might be an approach to systematically account for co-morbidities. The case mix index (CMI) is such an economic parameter that is calculated using diagnosis-related groups (DRGs), a measure that is nowadays routinely obtained in various countries as a basis for hospital reimbursement.¹⁶

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DRGs, developed as an instrument to relate the case mix of a hospital to the costs, classify patients depending on their diagnosis, treatments, age and other information into mutually exclusive, clinically and financially homogeneous categories. This is done by collecting information about a patient's medical needs and subsequently converting this information into codes. These codes describe patients' conditions, their severity of illness and their prognoses.¹⁷ DRGs were first developed in the 1960s at Yale University.^{16,18} Since then, DRGs or similar grouping systems have been installed by most European countries. Most classification methods are based, to some extent, on the HealthCare Financing Administration system that was introduced in 1983 under the US Medicare system. Despite this similarity, there are considerable differences in the methods for collecting cost data and reimbursement rates among different countries.^{16,19} Nevertheless, DRGs are a useful and simple tool for defining and measuring a hospital's case mix complexity.

Associations between CMI and antibiotic use have been studied in long-term care settings,^{20,21} but neither in large university hospitals with a wide variation of antibiotic use and CMIs across different departments, nor across various acute care hospitals. We therefore aimed to evaluate the correlation between antibiotic use and CMI in these two settings.

Methods

Study design

We performed a retrospective observational study of antibiotic use and CMI in different departments of the University Hospital, Zurich and in another 12 acute care hospitals in the Canton of Zurich, a state in Switzerland, during the study period between 1 January 2006 and 31 December 2006.

Case mix index

The CMI equals the sum of the total cost weights of all inpatients per a defined time period divided by the number of admissions. The 'cost weight' of a DRG X is defined by dividing the average cost per case of DRG X by the mean cost per case on a nationwide level. In this way, each DRG is allocated a cost weight. In Switzerland, cost weights are regularly recalculated and recorded in the database of APDRG Swiss.²²

Setting

The University Hospital Zurich is an 861 bed tertiary care teaching hospital. It covers all specialties except paediatrics and orthopaedics. The psychiatry ward was excluded from the analysis since cost weights for psychiatric patients have not yet been defined in Switzerland. About 1959 healthy newborns were cared for in the obstetrics department. In addition, the same department included a 23 bed neonatology ward. Six intensive care units (ICUs), including a burn unit, with a total of 59 beds are assigned to different departments. Bone marrow transplantations are performed in a specialized unit. In 2006, a total of 33 663 patients was admitted accounting for 243 235 bed-days (day of admission and day of discharge counted together as 1 bed-day).²³ The mean length of stay (LOS) in the wards, the ICUs and the bone marrow transplantation unit was 4.6 (range, 3.0–11.5), 3.7 (range, 3.1–5.8) and 20.8 days, respectively.

The other 12 hospitals of the Canton of Zurich included 10 primary and 2 secondary care hospitals. In 2006, the numbers of

beds of these hospitals ranged from 92 to 554, the number of intensive care beds from 4 to 16, the numbers of bed-days (day of admission and day of discharge counted together as 1 bed-day) from 22 521 to 152 674, the number of patients admitted from 3705 to 21 229 and the mean LOS from 4.3 to 18.4 days. An obstetrics department was part of all but one of the hospitals with numbers of newborns ranging from 321 to 1463. Paediatric wards were part of one primary care hospital and both secondary care hospitals. Two primary care hospitals included a long-term care unit, and one a psychiatry ward. None of the hospitals had a rehabilitation ward.²³ Most of the 13 hospitals had internal guidelines for antibiotic use.

Data collection

For the University Hospital Zurich, aggregate in-hospital antibiotic use data, including deliveries and returns, were collected from the hospital pharmacy and entered into a Microsoft® Office Access 2003 database, similar to ABC Calc developed by the Danish Statens Serum Institut.²⁴ Bed-days and numbers of admissions were calculated from computerized hospital administration records of each patient hospitalized for ≥ 24 h in the same hospital unit, counting the days of admission and discharge together as one bed-day. Defined daily doses (DDD)/100 bed-days and DDD/100 admissions were calculated for each hospital department. The 2007 version [Group 'J01 (Antibacterials for systemic use)'] of the ATC Index with DDDs was used.¹¹

CMIs for patients hospitalized in these defined patient care areas were calculated for the study year, using data provided by the Division of Medical Coding Statistics of the University Hospital Zurich based on cost weights for each patient. Version 1.6 of the APDRG Grouper and Version 5.1 of the Swiss APDRG cost weights were used.²² Diagnoses were coded with the ICD-10 WHO Version 1.3, and treatments were coded with CHOP Version 8.0, a Swiss translation of ICD-9-CM 2005. Cost weights of patients who were transferred between hospital departments were counted for the calculation of CMI of each location, accordingly.

For the other 12 hospitals of the Canton of Zurich, numbers of bed-days, admissions and CMIs are published on a yearly basis by the healthcare authorities of the Canton of Zurich.²³ Cumulative antibiotic use data for the year 2006 were obtained from the hospital pharmacy of each hospital. Calculations of antibiotic use data were carried out in analogy to the methods described earlier. The analyses were limited to somatic acute care units of the hospitals (excluding long-term care units), except for one hospital where a psychiatry ward and a long-term care unit could not be excluded due to local pharmacy data management reasons.

Statistical analysis

We used Stata (Version 9.2, StataCorp, College Station, TX, USA) for statistical analyses. Weighted linear regression analyses were performed to determine the correlation between antibiotic use and CMI. We used analytic weights according to the number of bed-days of each department or hospital to reduce variation induced by measures derived from smaller hospitals or departments. A *P* value < 0.05 was considered statistically significant.

Results

Antibiotic use

Antibiotic use data are depicted in Figure 1, and data on LOS in different hospitals are listed in the figure legend. At the

Antibiotic use and case mix

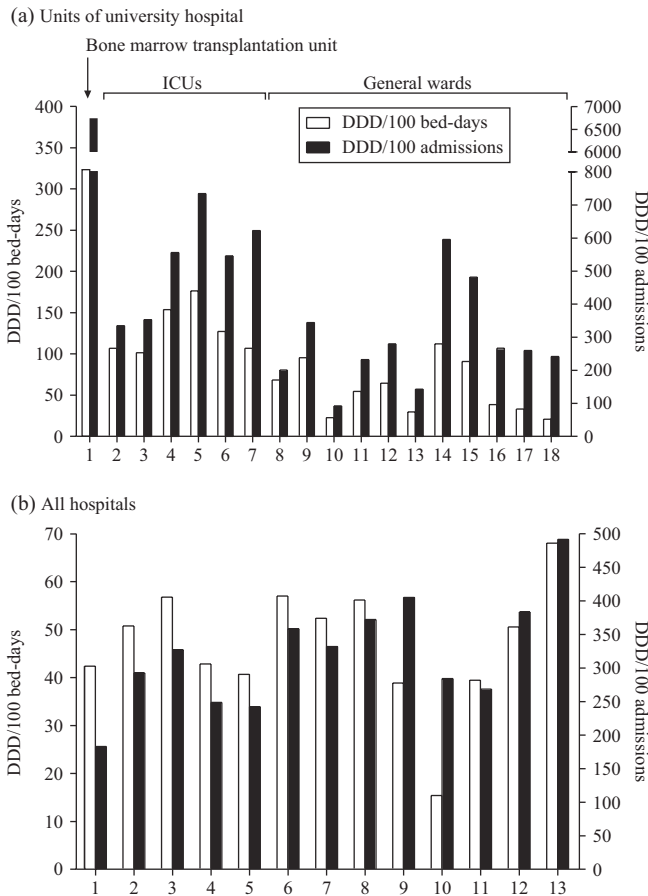


Figure 1. Antibiotic use. (a) Units of university hospital: 1, bone marrow transplantation unit (LOS = 20.8 days). 2–7, ICUs ordered by increasing mean LOS: 2, neurosurgical ICU (LOS, 3.1 days); 3, cardiac surgery ICU (LOS, 3.5 days); 4, medical ICU (LOS, 3.6 days); 5, general, thoracic and transplant surgery ICU (LOS, 4.2 days); 6, trauma ICU (LOS, 4.3 days); 7, burn ICU (LOS, 5.8 days); 8–18, different wards of departments, ordered by increasing mean LOS: 8, ophthalmology/ear–nose–throat (LOS, 3.0 days); 9, urology (LOS, 3.6 days); 10, gynaecology and obstetrics (LOS, 4.1 days); 11, surgery (cardiac, thoracic, visceral, trauma and reconstructive surgery) (LOS, 4.3 days); 12, neurosurgery (LOS, 4.3 days); 13, neurology (LOS, 4.8 days); 14, internal medicine (LOS, 5.3 days); 15, interdisciplinary private wards (LOS, 5.3 days); 16, dermatology (LOS, 6.9 days); 17, radiation therapy (LOS, 7.8 days); 18, rheumatology (LOS, 11.5 days). (b) All hospitals: 1–10, primary care hospitals, ordered by increasing mean LOS. LOS of different hospitals are 4.3, 5.8, 5.8, 5.8, 6.0, 6.3, 6.3, 6.6, 10.4 and 18.4 days, respectively. 11 and 12, secondary care hospitals, ordered by increasing mean LOS. LOSs of different hospitals are 6.8 and 7.6 days, respectively. 13, tertiary care university hospital (LOS, 7.2 days).

university hospital, overall antibiotic use was 68.04 DDD/100 bed-days and 491.62 DDD/100 admissions, respectively. The DDD/100 bed-days in the ICUs ranged from 101.31 to 176.23 and in the wards from 20.97 to 112.18. The highest antibiotic use with 323.37 DDD/100 bed-days was recorded in the bone marrow transplantation unit (Figure 1a).

In primary care hospitals, antibiotic use ranged from 15.45 to 57.05 DDD/100 bed-days and from 182.95 to 405.21 DDD/100 admissions (Figure 1b). The corresponding numbers for the two secondary care hospitals were 39.46 and 50.56

DDD/100 bed-days and 268.59 and 383.77 DDD/100 admissions, respectively.

Correlation between antibiotic use and CMI at the University Hospital

The CMI of the various units and departments described earlier ranged from 3.57 to 6.45 in the ICUs and from 1.01 to 3.02 on general wards. A CMI of 9.83 was calculated for the bone marrow transplantation unit. The correlation between antibiotic use and CMI is depicted in Figure 2. We found a significant correlation between CMI and antibiotic use when calculated in DDD/100 bed-days [$R^2 = 0.57$, $P = 0.0002$, slope = 27.90 DDD/100 bed-days per CMI (95% CI 15.71–40.08)] as well as in the DDD/100 admissions format [$R^2 = 0.48$, $P = 0.0008$, slope = 383.61 DDD/100 admissions per CMI (95% CI 186.18–581.05)].

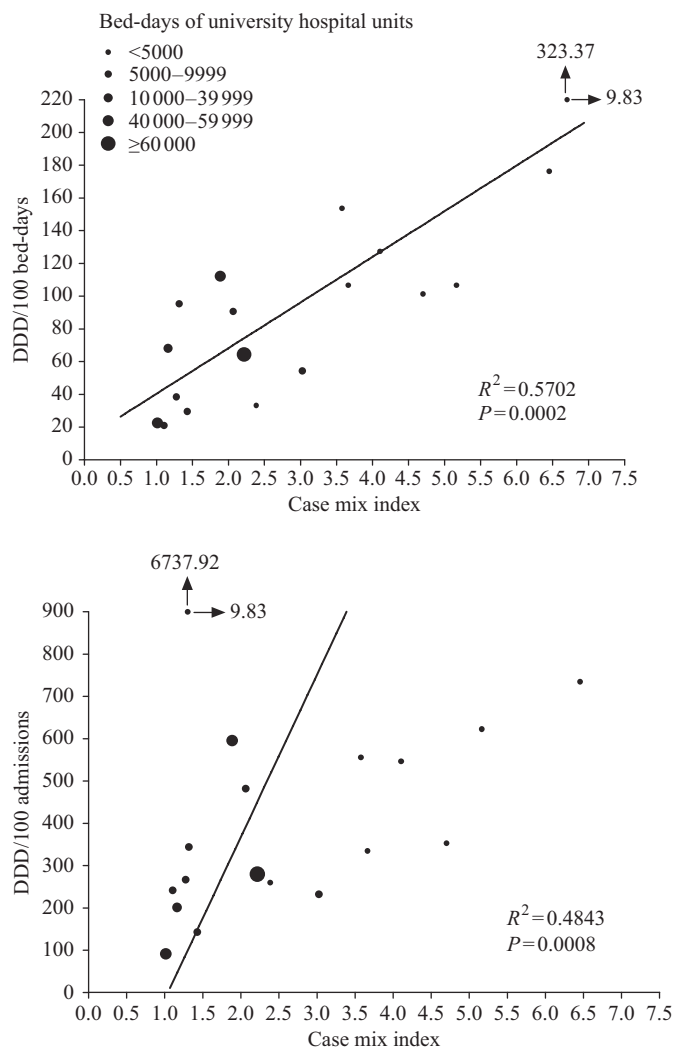


Figure 2. Correlation between antibiotic use and CMI in a tertiary care university hospital. Correlation between antibiotic use and CMI in different wards of the University Hospital Zurich in 2006 measured in DDD/100 bed-days (upper panel) and DDD/100 admissions (lower panel). Weighted linear regression was used with the size of the dots corresponding to the number of bed-days. DDD, defined daily doses. ‘Antibiotics’ are all substances of ATC group ‘J01 (Antibacterials for systemic use)’.

Correlation of antibiotic use and CMI at the 13 hospitals of the Canton of Zurich

The CMI of the 10 primary, the 2 secondary care hospitals and the tertiary care University Hospital ranged from 0.7853 to 1.3624. Correlations between antibiotic use and CMI across various hospitals of the greater Zurich area are displayed in Figure 3. There was a significant correlation between CMI and antibiotic use presented in the DDD/100 bed-days format [$R^2 = 0.46$, $P = 0.0065$, slope = 47.96 DDD/100 bed-days per CMI (95% CI 16.46–79.47)] as well as in the DDD/100 admissions format [$R^2 = 0.85$, $P < 0.0001$, slope = 403.25 DDD/100 admissions per CMI (95% CI 295.00–511.51)].

Discussion

The direct comparison of the quantity of antibiotic use between hospitals or hospital units is flawed due to differences in the

average severity of illness of patients hospitalized in specific institutions as well as due to different structures and missions of hospitals. There is no defined benchmark for antibiotic use for specific categories of hospitals (e.g. primary, secondary or tertiary care). The CMI is an economic surrogate marker used to describe the average morbidity of patients in hospitals. We found a moderate correlation between antibiotic use and CMI when analysing data of different departments and units of a tertiary care university hospital, as well as when comparing another 12 primary and secondary acute care hospitals in the Canton of Zurich, a state in Northern Switzerland. Such correlations were found when antibiotic use was calculated both in DDD/100 bed-days and in DDD/100 admissions. Consequently, we demonstrate that differences in antibiotic use in different wards as well as in various hospitals can be explained to a significant extent by differences in CMIs of patient populations admitted to individual hospitals, and thus by differences in patients' morbidities.

Data on the correlation of cost indicators and antibiotic use are scarce in the current literature. To the best of our knowledge, we present the first study to evaluate such a correlation between CMI and antibiotic use within a single institution and across various acute care hospitals. Previously, associations between CMI and antibiotic use have been studied in long-term care settings.^{20,21} Mylotte *et al.* reported the mean facility CMI (using the so-called Resource Utilization Groups II system) and the mean facility infection rate to significantly predict mean incidence of antibiotic use in a multilinear model. Furthermore, a trend towards a significant correlation between CMI and antibiotic use was observed by the simple linear regression analysis.²⁰ In another study, these authors found that after controlling for case mix variation and cost per antibiotic-day, variation in the infection rate explained most of the variation in incidence of antibiotic use.²¹

Our findings have the potential to introduce a novel method to detect variations in antibiotic prescribing within and between hospitals. Interpreting quantitative antibiotic use data of various hospital units that belong to different medical specialties is challenging due to the lack of possibilities to comprehensively measure, score and compare morbidities of all individual hospitalized patients. However, the identification of high antibiotic use on a hospital unit level may indicate inappropriate use and is furthermore crucial in order to detect areas with high antimicrobial selection pressure. Other reasons for variations in antibiotic prescribing include differences in physician prescribing preference or varying infection prevalence among hospital departments or hospitals. At present, however, no straightforward tools for continuous monitoring of infection prevalence in hospitals are available. Most hospitals assess the rate of nosocomial infections using periodic prevalence surveys.

Our approach identified hospital units where quantitative antibiotic use data cannot be explained by a high CMI. This quantitative signal now necessitates further individualized qualitative analyses in order to define whether interventions are required to improve antibiotic use in these units. Furthermore, this principle can also be applied to compare antibiotic use data between hospitals of a district or on a national level taking into account the different patient populations across various hospitals. However, the manner in which cost data are collected and reimbursement rates are calculated was found to differ among various countries,¹⁹ limiting international comparisons.

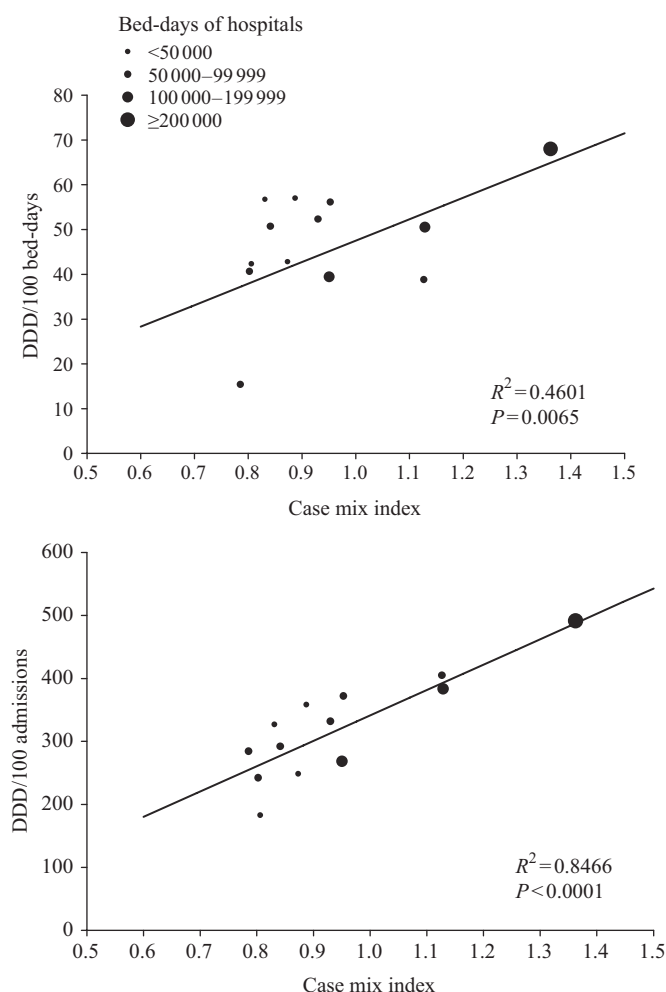


Figure 3. Correlation between antibiotic use and CMI in 13 acute care hospitals. Correlation between CMI and antibiotic use in 2006 in various hospitals of the greater Zurich area measured in DDD/100 bed-days (upper panel) and DDD/100 admissions (lower panel). Weighted linear regression was used with the size of the dots corresponding to the number of bed-days. DDD, defined daily doses. 'Antibiotics' are all substances of ATC group 'J01 (Antibacterials for systemic use)'.

Limitations of our study arise from the shortcomings of methods to calculate antibiotic use and CMI. Databases for DDD as well as for DRGs are updated regularly, i.e. definitions and variables change over time. Consequently, such updates may affect analyses of CMI and antibiotic use and its correlation, when different observation periods are compared. Therefore, we repeated the weighted regression analyses of the University Hospital data sets for the years 2004 and 2005 (using version 4.1 of the APDRG Swiss cost weights) and confirmed the significant correlation between antibiotic use and CMI: in 2004, the correlations between CMI and DDD/100 bed-days and DDD/100 admissions resulted in $R^2 = 0.69$ ($P < 0.0001$) and $R^2 = 0.53$ ($P = 0.0004$), respectively; and in 2005, the corresponding results were $R^2 = 0.72$ ($P < 0.0001$) and $R^2 = 0.56$ ($P = 0.0004$). Concerning antibiotic use, the bone marrow transplantation unit is an outlier among the departments of the university hospital, which might bias the correlation between the different hospitals of the Canton of Zurich. However, even if the bone marrow transplantation unit was excluded from the university hospital data, there was still a significant correlation between CMI and antibiotic use presented in the DDD/100 bed-days format [$R^2 = 0.41$, $P = 0.0113$, slope = 45.38 DDD/100 bed-days per CMI (95% CI 12.50–78.26)] as well as in the DDD/100 admissions format [$R^2 = 0.82$, $P < 0.0001$, slope = 386.04 DDD/100 admissions per CMI (95% CI 272.77–499.31)] for the 13 hospitals of the Canton of Zurich.

The ATC/DDD system is a well-accepted and widely used standard method for measuring antibiotic use, but some limitations have been discussed.^{4,13,25} For example, calculations of DDD/100 bed-days and DDD/100 admissions result in discrepant antibiotic use data because of the influence of LOS. Hospitals with a short mean LOS have a low antibiotic use when measured in DDD/100 admissions as opposed to DDD/100 bed-days, whereas hospitals with a long mean LOS (resulting in fewer admissions) show a relatively high antibiotic use, if measured in DDD/100 admissions. LOS is largely influenced by the type of services offered by a given hospital. If long-term care facilities or psychiatry wards are part of an acute care hospital, this results in a high mean LOS of these institutions, as relatively few patients in these units contribute a large number of bed-days. Nevertheless, we found both variables, DDD/100 bed-days and DDD/100 admissions, to similarly correlate with CMI. Furthermore, also cost weights are influenced by the length of hospital stay. Procedures or diseases requiring a long hospital stay are therefore assigned a higher cost weight irrespective of the clinical judgement of the severity of a disease. The costs of implants might further bias case mix calculations. As an example, implantable cardioverter-defibrillators are more expensive than pacemakers, whereas the LOS for the implantation or the type of complications arising from the underlying arrhythmias is similar. As it must be a prerequisite for a benchmark to be easily available, we did not make attempts to control for these biases, e.g. by excluding patients with implants or with extraordinarily long hospitalizations. Finally, whereas All Patient-Refined Diagnosis-Related Groups (APR-DRGs) are used in the USA to compare hospital performance by risk-adjusting mortality, LOS or inpatient charges,²⁶ it has not yet been formally evaluated whether APRDRGs indeed provide a reliable estimate of patient morbidity and mortality.

Other surrogate markers for case mix adjustment of hospital antibiotic use have been proposed. Lamoth *et al.*²⁷ observed that the numbers of blood samples drawn for bacterial culture

enabled accurate identification of periods with a drift in the antibiotic consumption in a medical ward. However, the authors stated that it was uncertain whether these results could be generalized to other settings, having found that the principle could not be applied in a general surgery ward. A few other studies have approached the problem of comparing different hospitals and different patient populations by categorizing hospitals according to their size or type,^{28,29} whereas others aimed at normalization by comparing antibiotic use among single medical specialties.^{29–31}

In conclusion, the CMI based on DRGs may be a valuable tool to facilitate the interpretation of quantitative hospital antibiotic use data and to identify areas of concern. Advantages of this measure are that it can be obtained more easily than laborious morbidity scores, that it is based on nationwide economic data and that it appears to generate more generalizable data sets than self-defined case mix measures.^{15,27,32} Further studies are needed to determine the role of the various measures that are proposed for the interpretation of quantitative antibiotic use, to assess the generalizability of our results and to compare CMI and DRGs (or similar systems) of different countries with hospital antibiotic use.

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